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Teaching Newton's Laws in the Age of Artificial Intelligence: A Collaborative Work Experience

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ABSTRACT

This study presents an educational intervention aimed at evaluating the impact of the use of artificial intelligence (AI) tools on the resolution of dynamics exercises. A comparative analysis was carried out between two groups of second year high school students: a control group that received classes using a traditional methodology and an experimental group that, in addition to traditional classes, used ChatGPT as a support in assisted exercise solving. The evaluation activity consisted of a collaborative workshop, where the experimental group used ChatGPT as a support tool. To measure the academic performance of the students in this workshop, a rubric was designed in spreadsheets, with a numerical scale accompanied by its qualitative equivalence. The nonparametric Mann-Whitney test was used to compare the scores of both groups, since the scores are not normal. The results indicated significant differences in the criteria related to the procedural and interpretative development of the resolution of exercises, with the experimental group standing out with a higher performance than the control group. Likewise, the perception and satisfaction of the participants of the experimental group regarding the use of ChatGPT was measured, who expressed a favorable evaluation. It is concluded that, with adequate guidance, the integration of AI in the classroom and collaborative work is presented as a promising alternative to guide students in solving dynamic problems.

Keywords: Exercise solving, collaborative work, ChatGPT

1.-INTRODUCTION

The famous English physicist Sir Isaac Newton, in 1687, published *Philosophiae Naturalis Principia Mathematica*, a fundamental work that exposes the laws of mechanics, which have been crucial to understanding the functioning of the universe. These laws have not only revolutionized scientific thought, but have also profoundly marked the development of modern physics (Moreno, 2011). In the field of education, their relevance is such that Newton's laws are an essential part of the minimum contents in secondary education curricula and are present in the training programs of future teachers, scientists, and engineers (Montino & Chiabrando, 2019).

However, the difficulties faced by students in learning Newton's laws and their applications are wide and diverse (Barragán, 2011; Khiari, 2011). These difficulties are reflected in the low pass rates in introductory physics courses at various educational levels, where a large part of the content is focused on solving dynamic problems. Despite advances in teaching-learning strategies in physics, and the educational advantages offered by the incorporation of technologies in education, teachers in charge of teaching physics in schools rarely implement innovative methodologies in their practice. This is due, to a large extent, to the tendency to repeat the way in which they were "instructed", that is, through the traditional approach, where the teacher, as an expert, gives a master class with hardly any interaction with the students (Ramírez, 2010). Consequently, the low pass rates and the traditional instructional approach highlight the need to incorporate innovative elements into physics teaching, especially in the resolution of dynamics problems. These challenges prompt reflection on new methodologies that not only improve the understanding of fundamental concepts, but also promote greater student interaction and participation in the learning process.

In relation to the above, collaborative work and the integration of tools based on artificial intelligence (AI) are presented as innovative alternatives of the educational process. Collaborative work, by encouraging the exchange of ideas and joint problem solving, not only reinforces students' understanding, but also helps them develop soft skills such as communication and critical thinking (Serrano & Prendes, 2012). For its part, AI, especially with the popularization of tools such as ChatGPT since 2022, offers interactive support that can facilitate the resolution of

dynamic problems, providing instant feedback and allowing students to explore different approaches in a personalized way. The impact of AI is so significant that several experts consider it the future of teaching, learning, and educational research (Segarra, Grangel, & Belmonte, 2024).

With the aim of highlighting the advantages of collaborative work and the integration of artificial intelligence (AI) in the classroom, this research evaluates the impact of the use of AI tools on the resolution of dynamic exercises. The study is developed from a comparative analysis between two groups: a control group and an experimental group. Both groups were given a class on solving classical problems related to Newton's laws, with the key difference that the experimental group was instructed in the use of ChatGPT for assisted exercise solving. To evaluate the knowledge acquired, they were assigned a collaborative workshop in which the teams had to apply dynamic concepts for problem solving, where the experimental group was instructed to integrate the use of AI as a support in solving the exercises. In addition, they were asked to make a critical comparison between their results and those generated by ChatGPT. As an evaluation instrument, a rubric was designed in an Excel spreadsheet, using a numerical scale with its qualitative equivalent. Subsequently, a non-parametric Mann-Whitney test was applied in order to statistically compare the scores obtained by both groups. Additionally, a questionnaire with a Likert scale was implemented to analyze the perception and satisfaction of the participants of the experimental group in relation to the use of ChatGPT in the resolution of dynamic problems. Finally, the results obtained were analyzed and the main conclusions of the study are presented.

2.-METHODOLOGY

2.1. Context and design of the research

The study was carried out at the Eugenio Espejo Educational Unit, located in the canton of Chone, Manabí-Ecuador. The sample was made up of second-year high school students divided into two groups: a control group with 28 students and an experimental group with 32 students. A comparative design was used between both groups, where the experimental group integrated the use of artificial intelligence (ChatGPT) as a learning resource.

2.2. Educational intervention

A class was given to the previously mentioned groups on the resolution of classic dynamic exercises, focused on situations such as masses on inclined planes and pulley systems connected by ropes. The classes followed the didactic strategy proposed by Serway and Jewett (2008), which includes the following steps:

- *Represent*: Drawing of the physical system or problem, generating a mental representation of it. Some exercises already include it in their statements.
- *Conceptualize*: Identification of the data provided in the problem statement and the unknowns, along with the elaboration of free-body diagrams to represent external forces.
- *Analyze*: Apply Newton's Second Law, decompose the vector components of forces, solve the equations for unknowns, and replace quantities with their units.
- *Finish:* Present the results, verify their consistency and offer an appropriate interpretation.

Once the explanation was finished, a space was opened for questions and discussion in both groups. The key methodological difference lies in the fact that, while the control group received the class in the traditional way (using a marker and blackboard), the experimental group was integrated with ChatGPT as a support in solving exercises. These students were instructed in the use of "prompts" to compare procedures, verify results, and obtain accurate interpretations.

The use of ChatGPT was selected due to its accessibility, popularity, and ease of use, allowing students to use it as a scaffolding resource during class. To evaluate the knowledge taught, both groups held a collaborative workshop on solving dynamic problems, following the previously exposed strategy. It is important to note that the students in the experimental group were asked to use ChatGPT, indicating the degree of similarity between their own developments and those generated by the AI. This group activity also had the purpose of promoting soft skills, such as collaborative work.

2.3. Data collection and analysis

To evaluate the performance of the students of both courses, an evaluation rubric designed in Excel was used that included criteria and indicators based on the problem-solving strategy explained in class, see Figure 1. Each criterion

has a maximum value of 1 point, with rating options on a scale of [0, 1], in 0.1 intervals. It is important to note that the instrument is on a numerical scale with its qualitative equivalent shown in Table 1. Thanks to Excel functions, such as filters, data validation and logical formulas, an instrument was designed that allows the qualification process to be optimized and facilitates the analysis of the results. The data is presented in a bar chart showing the distribution of grades for both groups. To determine whether there were significant differences between the scores of the groups in each evaluation criterion, Student's t-test and the non-parametric Mann-Whitney test were applied, choosing one or the other according to the normality of the data. These statistical analyses were performed using SPSS software.

Table 1. Grading scale of the evaluation rubric

Numerical scale	Qualitative scale
9.1 to 10.0	Excellent
8.1 to 9.0	Well
7.0 to 8.0	Satisfactory
< 7	Deficient

To assess the level of perception and satisfaction with the use of ChatGPT in solving dynamic exercises, students in the experimental group were given an online questionnaire with 10 questions using a 5-point Likert scale. This instrument was divided into four parts that seek to investigate the students:

- *Consistency in AI problem-solving*: Comparison between the exercises developed by the students and those generated by ChatGPT.
- *Experience in the use of AI*: General perception about the use of AI for the resolution of dynamics exercises.
- *Collaborative work*: Opinion on the experience of working collaboratively in the learning context.
- *General satisfaction*: Rating of the level of liking of the use of the artificial intelligence tool in the resolution of physics exercises.

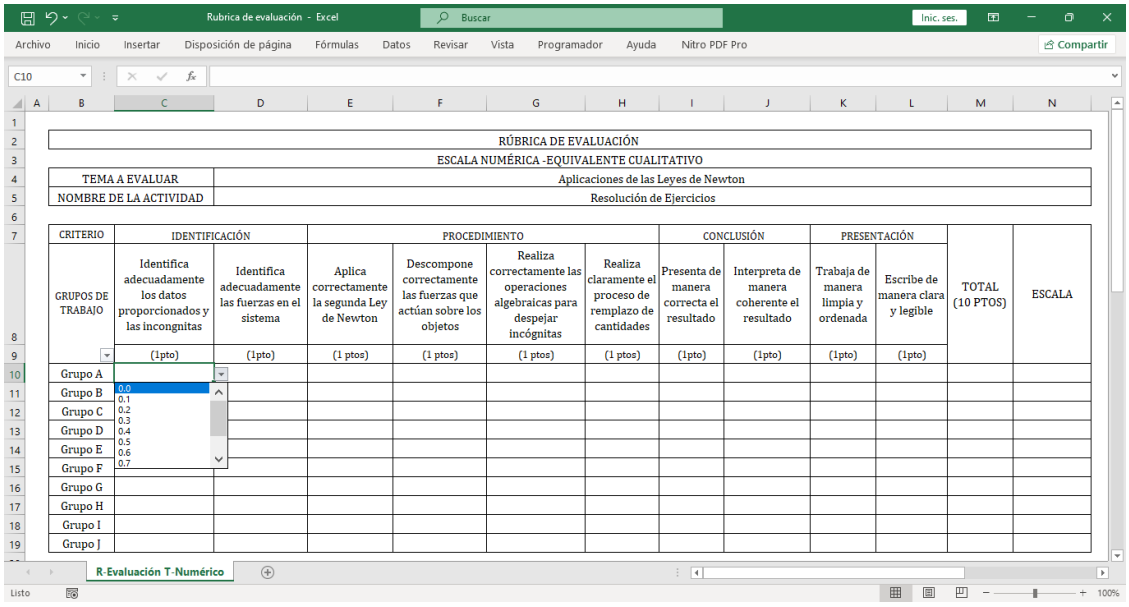

Figure 1: Evaluation Rubric made in Excel

The statistical treatment of the data was carried out using the SPSS software and the Excel spreadsheet. To measure the reliability of the answers obtained in the questionnaire, Cronbach's alpha was calculated, the value of which is presented in Table 2, (Watson et al., 2023 ; Giday & Perumal, 2024). This table shows the reliability index, indicating the internal consistency and validity of the instrument used. In addition, the results on the perception and satisfaction

of the students were analyzed using a bar graph that represents the percentages in five levels: very high, high, moderate, low and very low.

3.-RESULTS

3.1-Comparison of group ratings

After the workshops, the groups were graded using the evaluation rubric in Excel, shown in Figure 1. The appendices present the scores obtained by the work teams of both groups. The normality test showed that the data did not follow a normal distribution, which led to the application of the nonparametric Mann-Whitney test to compare the scores between the groups in the different evaluation criteria.

Figure 2 shows that the p-values obtained for the criteria of "Identification" (0.4447) and "Presentation" (0.8875) indicate that there is no significant difference between the two groups, which suggests a similar performance in these aspects. These results may be because such criteria involve more basic and automated skills, such as identifying elements in a problem and presenting them, where AI would not have a noticeable impact.

p-value Comparison Across Evaluation Criteria

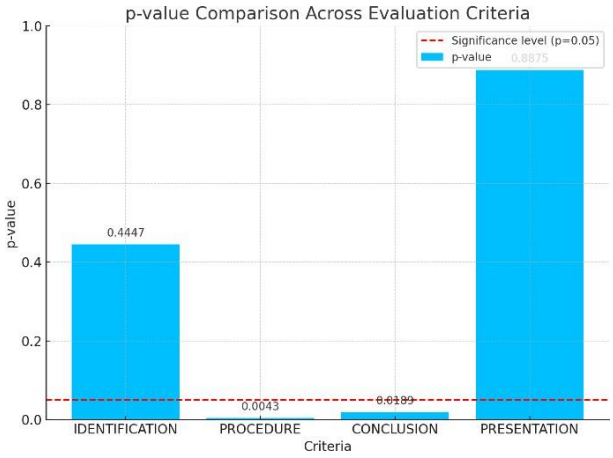

Figure 2: P-value of the evaluated criteria

On the other hand, the p-values for the criteria of "Procedure" (0.0043) and "Conclusion" (0.0189) reveal a significant difference between both groups, indicating that the experimental group performed better in the ratings. This suggests that AI, by facilitating the process of decomposition and analysis of complex problems, allowed the experimental group to excel in the procedural execution of the exercises and in the interpretation of the results. These findings reinforce the idea that, in tasks that require a higher level of logical reasoning and abstract thinking, the use of AI can offer significant support.

Figure 3 presents a bar graph that compares the performance of both groups according to the rating scales established in the evaluation instrument. While 60% of the teams in the experimental group earned a rating of "Excellent," only 10% of the teams in the control group achieved this level. On the other hand, 40% of the teams in both groups earned a rating of "Good", demonstrating a similar performance at this level. However, the control group showed a more dispersed performance, with 40% of its teams receiving a rating of "Satisfactory" and 10% being rated as "Deficient", categories that were not present in the experimental group.

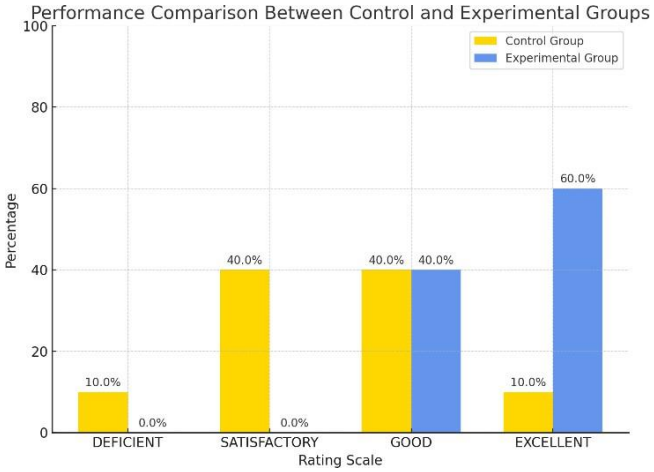

Figure 3: Comparison of qualification level between the control and experimental group

These results suggest that the use of ChatGPT provided the students of the experimental group with a guide to solve dynamics problems, particularly in the procedural and conclusive aspects of the exercises, such as the vector treatment of forces, the clearing of unknowns through algebraic operations, the replacement of units, and the correct presentation and interpretation of the results. The absence of "Satisfactory" or "Poor" ratings in the experimental group underscores how AI contributed to improving both accuracy and comprehension in intermediate problem-solving processes. In contrast, the control group, relying exclusively on traditional methods, showed greater dispersion in their performance, with several teams facing difficulties in achieving the highest levels of performance.

3.2-Perception and satisfaction of the use of Chat-GPT

However, the results of the statistical treatment of the post-workshop surveys applied to the experimental group are presented. Table 2 shows that Cronbach's alpha coefficient was 0.85, indicating a "Good" level of reliability. Consequently, the instrument is reliable and the survey questions maintain internal coherence, reflecting consistent responses from the participants.

Table 2. Reliability Statistics

Cronbach's alpha	N of elements	Weighting (Cronbach's alpha coefficient)	Magnitude
0.83	10	0.91 to 1.00	Excellent
		0.81 to 0.90	Well
		0.71 to 0.80	Acceptable
		0.61 to 0.70	Questionable
		0.51 to 0.60	Poor
		< 0.5	Unacceptable

Figure 4 shows that, in the first category of consistency in AI problem-solving, the results obtained for questions P1 to P4 reflect a mixed assessment. As for the coincidence of the numerical result obtained compared to that provided by ChatGPT (P1), 65.2% of the participants rated it as Moderate, while 26.1% rated it as High. This suggests that most of the students found reasonable, but not perfect, matches between their results and those obtained by the AI. Regarding the similarity in the mystery clearing operation (P2), 60.9% considered the similarity as Moderate, and 26.1% rated it as High. In relation to vector decomposition (P3), 69.6% indicated a Moderate similarity, while only 21.7% rated it as High. Finally, regarding the similarity in the use of physical units (P4), 56.5% rated this similarity as Moderate, and 30.4% as High.

In the second category, experience in using AI, which encompasses questions P5 to P8, the level of clarity and ease of understanding of the solutions provided by ChatGPT (P5) was considered Moderate by 52.2% of participants and High by 39.1%, indicating that although students generally found the answers helpful, They were not always completely clear. Regarding the accuracy and consistency of ChatGPT (P6) solutions, 52.2% rated them as Moderate, and 39.1% as High. As for ChatGPT's support for improving understanding of problems (P7), 43.5% rated it as High, suggesting that many students found AI a useful resource to better understand dynamics problems. In addition, 30.4% rated their confidence in solving similar problems after using ChatGPT (P8) as High, while 56.5% rated it as Moderate, indicating that the tool helped increase students' confidence, but with some moderation.

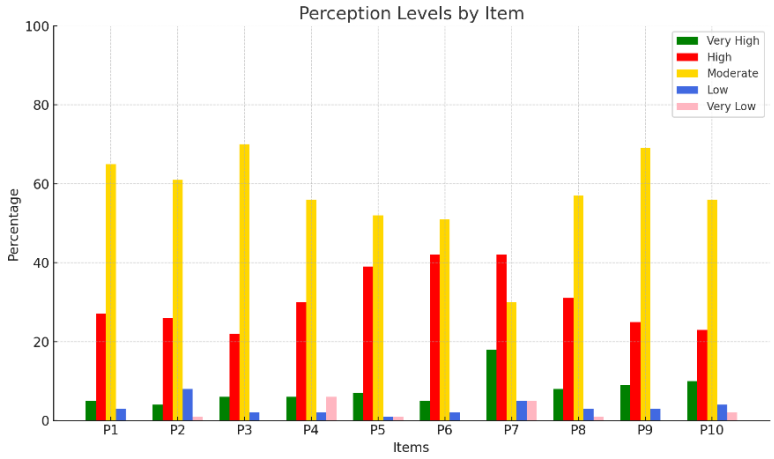

Figure 4. Statistics on the perception and satisfaction of the use of ChatGPT

Regarding the category of "collaborative work", represented by question P9, it was observed that 69.6% of the participants rated the impact of collaborative work during the workshop as Moderate, while 21.7% considered it High. This suggests that teamwork was perceived as useful, but that its effect was not equally strong on all students.

Finally, in the "general satisfaction" category (P10), 56.5% of the students indicated that their level of satisfaction with the use of ChatGPT in the workshop was Moderate, while 21.7% rated it as High and 17.4% as Very High. This reflects a generally positive perception about the use of AI, although it was not universally regarded as excellent by all students.

Indeed, the results show that the implementation of ChatGPT as a support tool in solving dynamic problems was well received by students, especially in terms of clarity, precision, and support to improve the understanding of concepts. However, while AI contributed to greater confidence and consistency in problem-solving, students did not always find numerical results and procedures to be completely consistent with those obtained manually. Collaborative work was rated as moderately enriching, and overall satisfaction with the use of AI was positive, although with room for improvement in its perceived effectiveness. These findings reinforce the idea that tools such as ChatGPT can complement the learning process, but their effectiveness depends on interaction and adaptation with the student

4.-CONCLUSIONS

The study shows that students expressed a favorable perception regarding the use of AI, although its effectiveness depends largely on how it is integrated into the educational process. The significant differences in the Procedure and Conclusion criteria scores between the control group and the experimental group suggest that tools such as ChatGPT can provide valuable support in complex subjects that require logical and abstract reasoning. With proper guidance, AI can help students break down problems, identify solutions, and perform more accurate analyses, making it easier to understand complex procedures and draw informed conclusions. However, it is important to note that AI does not replace students' critical reasoning, but acts as a complementary resource that reinforces and supports the learning process.

Dynamic problem-solving entails multiple challenges for students. These range from reading comprehension of the problem, through the conceptualization of the physical laws involved, the graphic representation of the scenario, to mathematical operations, such as vector treatment and the clearing of unknowns. In addition, the process of verifying the consistency of the units and the coherent interpretation of the results is usually an arduous task that, in many

cases, generates frustration and demotivation towards the subject involved. In this context, the use of AI tools, combined with collaborative work, offers an alternative solution that can help overcome these obstacles, providing students with guidance that allows them to advance in the problem-solving process and maintain a greater interest in their learning.

Considering that artificial intelligence is increasingly present in all areas of our society, its adoption in educational environments is inevitable. Teachers must be trained in the use of AI to guide students in how to interact with these technologies, aligning their teaching with the competencies that will be in demand in the future. In particular, ChatGPT can not only contribute to the solution of dynamics problems, but can also be used in other areas of physics, such as electromagnetism, and in mathematics subjects. It is also critical that teachers teach students to question and critically evaluate the information provided by AI, recognizing that it does not always represent the absolute truth.

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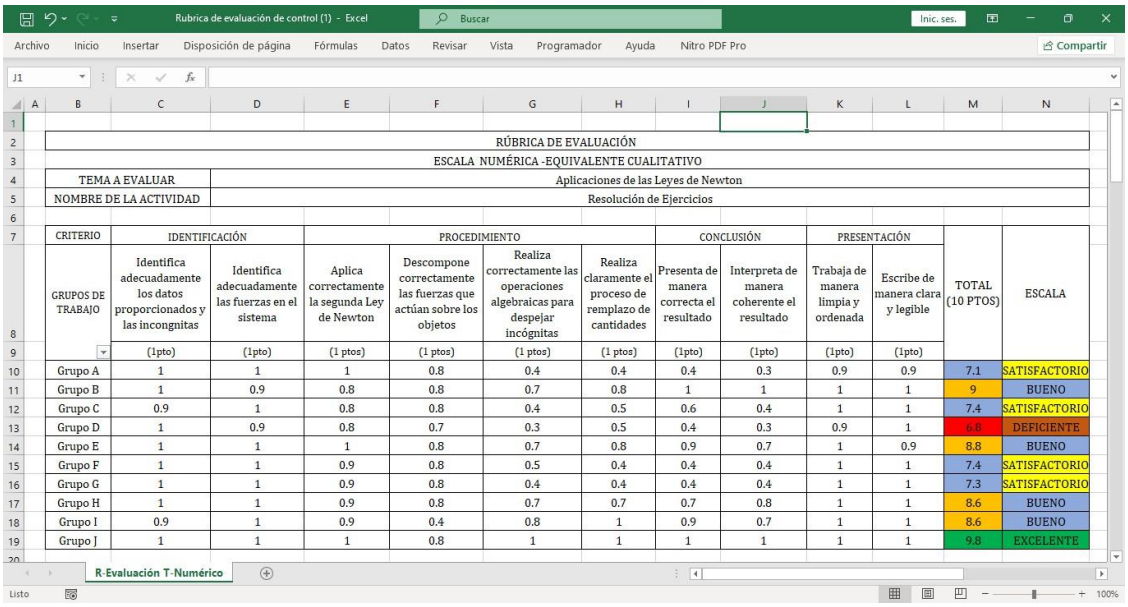
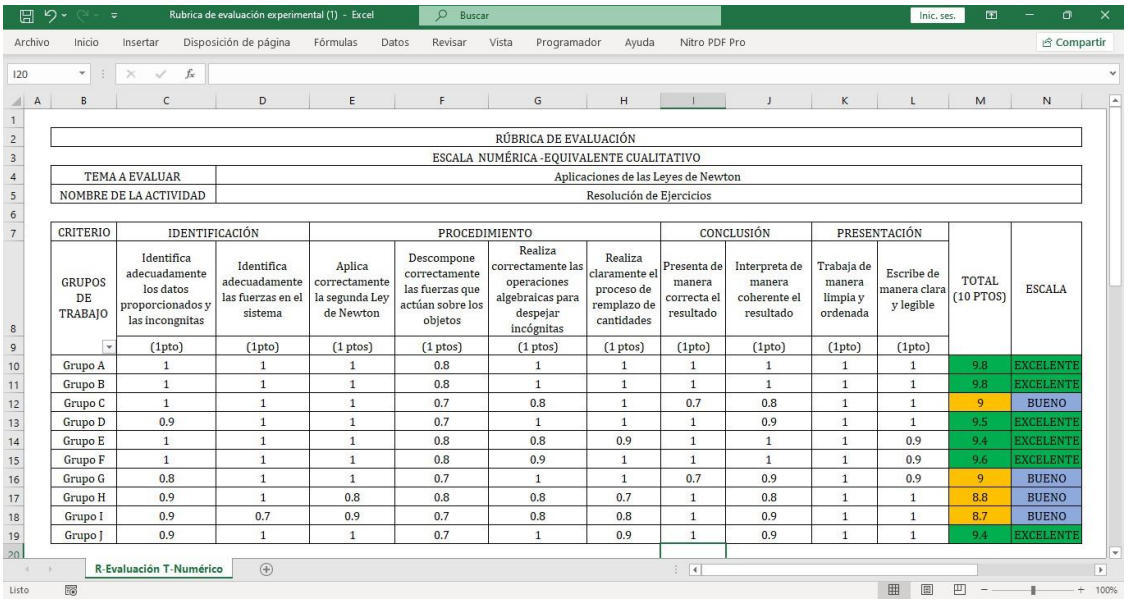
APPENDIX

Workshop scores obtained by the control group



RÚBRICA DE EVALUACIÓN												
ESCALA NUMÉRICA -EQUIVALENTE CUALITATIVO												
TEMA A EVALUAR	Aplicaciones de las Leyes de Newton											
NOMBRE DE LA ACTIVIDAD	Resolución de Ejercicios											
CRITERIO	IDENTIFICACIÓN		PROCEDIMIENTO				CONCLUSIÓN		PRESENTACIÓN		TOTAL (10 PTOS)	ESCALA
GRUPOS DE TRABAJO	Identifica adecuadamente los datos proporcionados y las incongnitas	Identifica adecuadamente las fuerzas en el sistema	Aplica correctamente la segunda Ley de Newton	Descompone correctamente las fuerzas que actúan sobre los objetos	Realiza correctamente las operaciones algebraicas para despejar incógnitas	Realiza claramente el proceso de remplazo de cantidades	Presenta de manera correcta el resultado	Interpreta de manera coherente el resultado	Trabaja de manera limpia y ordenada	Escribe de manera clara y legible		
	(1pto)	(1pto)	(1 ptos)	(1 ptos)	(1 ptos)	(1 ptos)	(1pto)	(1pto)	(1pto)	(1pto)		
Grupo A	1	1	1	0.8	0.4	0.4	0.4	0.3	0.9	0.9	7.1	SATISFACTORIO
Grupo B	1	0.9	0.8	0.8	0.7	0.8	1	1	1	1	9	BUENO
Grupo C	0.9	1	0.8	0.8	0.4	0.5	0.6	0.4	1	1	7.4	SATISFACTORIO
Grupo D	1	0.9	0.8	0.7	0.3	0.5	0.4	0.3	0.9	1	6.8	DEFICIENTE
Grupo E	1	1	1	0.8	0.7	0.8	0.9	0.7	1	0.9	8.8	BUENO
Grupo F	1	1	0.9	0.8	0.5	0.4	0.4	0.4	1	1	7.4	SATISFACTORIO
Grupo G	1	1	0.9	0.8	0.4	0.4	0.4	0.4	1	1	7.3	SATISFACTORIO
Grupo H	1	1	0.9	0.8	0.7	0.7	0.7	0.8	1	1	8.6	BUENO
Grupo I	0.9	1	0.9	0.4	0.8	1	0.9	0.7	1	1	8.6	BUENO
Grupo J	1	1	1	0.8	1	1	1	1	1	1	9.8	EXCELENTE

Ratings obtained by the experimental group



RÚBRICA DE EVALUACIÓN												
ESCALA NUMÉRICA -EQUIVALENTE CUALITATIVO												
TEMA A EVALUAR	Aplicaciones de las Leyes de Newton											
NOMBRE DE LA ACTIVIDAD	Resolución de Ejercicios											
CRITERIO	IDENTIFICACIÓN		PROCEDIMIENTO				CONCLUSIÓN		PRESENTACIÓN		TOTAL (10 PTOS)	ESCALA
GRUPOS DE TRABAJO	Identifica adecuadamente los datos proporcionados y las incongnitas	Identifica adecuadamente las fuerzas en el sistema	Aplica correctamente la segunda Ley de Newton	Descompone correctamente las fuerzas que actúan sobre los objetos	Realiza correctamente las operaciones algebraicas para despejar incógnitas	Realiza claramente el proceso de remplazo de cantidades	Presenta de manera correcta el resultado	Interpreta de manera coherente el resultado	Trabaja de manera limpia y ordenada	Escribe de manera clara y legible		
	(1pto)	(1pto)	(1 ptos)	(1 ptos)	(1 ptos)	(1 ptos)	(1pto)	(1pto)	(1pto)	(1pto)		
Grupo A	1	1	1	0.8	1	1	1	1	1	1	9.8	EXCELENTE
Grupo B	1	1	1	0.8	1	1	1	1	1	1	9.8	EXCELENTE
Grupo C	1	1	1	0.7	0.8	1	0.7	0.8	1	1	9	BUENO
Grupo D	0.9	1	1	0.7	1	1	1	0.9	1	1	9.5	EXCELENTE
Grupo E	1	1	1	0.8	0.8	0.9	1	1	1	0.9	9.4	EXCELENTE
Grupo F	1	1	1	0.8	0.9	1	1	1	1	0.9	9.6	EXCELENTE
Grupo G	0.8	1	1	0.7	1	1	0.7	0.9	1	0.9	9	BUENO
Grupo H	0.9	1	0.8	0.8	0.8	0.7	1	0.8	1	1	8.8	BUENO
Grupo I	0.9	0.7	0.9	0.7	0.8	0.8	1	0.9	1	1	8.7	BUENO
Grupo J	0.9	1	1	0.7	1	0.9	1	0.9	1	1	9.4	EXCELENTE